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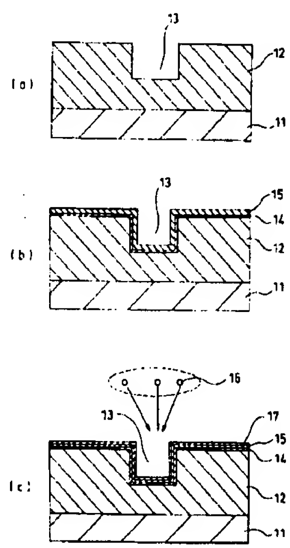
(54)【発明の名称】　埋め込み配線形成方法

(57)【要約】

【課題】　凹部を有する高融点導電性材料膜に対してプラズマ窒化を行なうにも拘らず、高融点導電性材料膜における凹部の側壁部にも確実に高融点導電性材料の窒化膜が形成されるようにする

【解決手段】　真空槽内に設けられた試料台上に、凹状溝１３を有するシリコン酸化膜１２が表面に形成されているシリコン基板１１を保持した後、シリコン酸化膜１２の上に、チタン膜１４及びタングステン膜１５を順次堆積する　真空槽内を１０Ｐａ以上の圧力に保持した状態でタングステン膜１５の表面部をプラズマ窒化して窒化タングステン膜１７を形成する　窒化タングステン膜１７の上に銅膜を堆積した後、チタン膜１４、タングステン膜１５、窒化タングステン膜１７及び銅膜における凹状溝１３の外側に位置する部分を除去して、銅からなる埋め込み配線を形成する



【特許請求の範囲】

【請求項１】　半導体基板上の絶縁膜に凹部を形成する第１の工程と、

前記絶縁膜の上に高融点導電性材料を堆積することにより、該高融点導電性材料からなり前記絶縁膜の凹部と対応する部位に凹部を有する第１の導電膜を形成する第２の工程と、

１０Ｐａ以上の圧力に保たれた真空槽内に前記半導体基板を保持して前記第１の導電膜の表面部をプラズマ窒化することにより、前記高融点導電性材料の窒化物からなり前記第１の導電膜の凹部と対応する部位に凹部を有する第２の導電膜を形成する第３の工程と、

前記第２の導電膜の上に配線用金属を前記第２の導電膜の凹部に前記配線用金属が埋め込まれるように堆積することにより、前記配線用金属からなる金属膜を形成する第４の工程と、

前記第１の導電膜、第２の導電膜及び金属膜における前記絶縁膜の凹部の外側に位置する部分を除去して、前記第２の導電膜の凹部内に前記配線用金属からなる埋め込み配線を形成する第５の工程とを備えていることを特徴とする埋め込み配線形成方法

【請求項２】　前記第３の工程は、５０Ｐａ以上の圧力に保たれた前記真空槽内に前記半導体基板を保持して前記第１の導電膜の表面部をプラズマ窒化する工程を含むことを特徴とする請求項１に記載の埋め込み配線形成方法

【請求項３】　前記第４の工程における配線用金属は銅又は銅合金であることを特徴とする請求項１に記載の埋め込み配線形成方法

【請求項４】　前記第２の工程における高融点導電性材料はチタン、タンタル又はタングステンであることを特徴とする請求項１に記載の埋め込み配線形成方法

【請求項５】　前記第３の工程は、前記半導体基板をアース電位又は正電位に保持した状態でプラズマ窒化を行なう工程を含むことをことを特徴とする請求項１に記載の埋め込み配線形成方法

【請求項６】　前記第２の工程は、ＣＶＤ法により前記高融点導電性材料を堆積する工程を含むことを特徴とする請求項１に記載の埋め込み配線形成方法

【請求項７】　前記第２の工程は、前記高融点導電性材料の結晶化が抑えられる温度領域で該高融点導電性材料を堆積することにより、該高融点導電性材料の少なくとも一部がアモルファスな状態で前記第１の導電膜を形成する工程を含むことを特徴とする請求項６に記載の埋め込み配線形成方法

【発明の詳細な説明】

【０００１】

【発明の属する技術分野】本発明は、半導体集積回路装置の製造工程等において、絶縁膜に形成された凹状溝等の凹部に配線用金属を埋め込んで埋め込み配線を形成する方法に関し、特に、配線用金属が酸化したり絶縁膜中に拡散したりする事態を防止する技術に関する

【０００２】

【従来の技術】現在、半導体集積回路装置等に用いられている配線用金属としてはアルミニウム合金が用いられることが多いが、アルミニウム合金と比較して抵抗が低く且つエレクトロマイグレーション耐性に優れている銅又は銅合金が次世代の配線用金属として有望視されている

【０００３】銅又は銅合金からなる銅配線の実用化に対する最大の課題は、銅配線の酸化の防止、銅配線の絶縁層中への拡散の防止及び銅膜に対する加工性である　特に、銅配線を構成する銅又は銅合金は、層間絶縁膜として用いられるSiO_2膜により酸化したり、SiO_2膜中に拡散したりし易いので、層間絶縁膜の下に形成されているトランジスタ等デバイスに悪影響を与える虞れがある　そこで、銅配線と層間絶縁膜との間に各種のバリア層を形成することが提案されている

【０００４】特開平０２－２４０９２０号には、Ｃｕ－Ｔｉ合金に対して８００Ｃの温度下におけるN_2アニールを行なってＴｉＮ膜からなるバリア層を形成することにより銅の酸化及び拡散を防止する方法が提案されている

【０００５】また、特開平０６－２７５６２３号や" Diffusion Barrier Properties of Transition Metals and Their Nitrides for Cu Interconnections" T.Nakao et.al., VMIC(1994)には、Ｗ膜に対してＥＣＲプラズマ法によるプラズマ窒化を行なって窒化タングステン膜からなるバリア層を形成する方法が提案されている

【０００６】

【発明が解決しようとする課題】ところで、銅又は銅合金からなる銅配線を用いて多層金属配線を形成する場合、下層の銅配線の酸化及び拡散を抑制するためには、バリア層に対する熱処理の温度を６００Ｃ以下に抑える必要があるが、前者の方法のように６００Ｃ以下の温度下におけるN_2アニールではＴｉＮ膜を形成することができない　一方、８００Ｃ程度の温度下におけるN_2アニールによりＴｉＮ膜を形成すると、下層の銅配線の酸化及び拡散の問題が起きてしまう　従って、N_2アニールによるバリア層の形成と銅配線の採用とは両立し難いという問題がある

【０００７】後者の方法は、低温により均一なバリア層を形成できるため、下層の銅配線の酸化及び拡散という問題は起こらないので、プラズマ窒化によるバリア層の形成と銅配線の採用とは両立可能である　ところが、銅はアルミニウムと異なり、ハロゲン化合物が不揮発性であるため、銅膜に対してドライエッチングを行なって銅配線を形成することは非常に困難である

【０００８】そこで、絶縁膜における配線形成領域に凹状溝を形成した後、全面に亘って銅を堆積して凹状溝に

銅が埋め込まれるように銅膜を形成し、その後、銅膜における凹状溝の外側の部分を除去して銅からなる埋め込み配線を形成する方法が提案されている

【0009】ところで、埋め込み配線形成方法により銅配線を形成する場合には、凹状溝の底部のみならず側壁部にもバリア層を形成しておかなければならない。特開平06-275623号においては、前述したように、凹状溝の底部及び側壁部に金属を堆積して金属膜を形成した後、該金属膜に対してECRプラズマ法によるプラズマ窒化を行なうことにより、前記金属の窒化膜からなるバリア層を形成しており、このときの処理圧力は1mTorrとしている

【0010】ところが、1mTorrにおいてプラズマ窒化を行なって金属の窒化膜からなるバリア層を形成する従来の方法には、図6(a)、(b)に示すような問題がある。図6(a)は、シリコン基板11の上にシリコン酸化膜12を堆積した後、該シリコン酸化膜12に凹状溝13を形成し、次に、シリコン酸化膜12の上に全面に亘ってタングステン膜15を堆積した後、プラズマ窒化法によりタングステン膜15の表面に窒化タングステン膜17を形成する工程を示している。1mTorrにおける窒素イオンの平均自由工程は10cm以上であって、プラズマ発生領域と基板との間のシース領域のシース長(約3mm)に比べてかなり大きいので、シース領域において窒素イオンが窒素分子と衝突する可能性は極めて低い。このため、図6(a)に示すように、窒素イオン16はシリコン基板11に対してほぼ垂直な方向から入射する。従って、窒素イオン16はタングステン膜15における凹状溝13の側壁部には殆ど到達することがないため、タングステン膜15の凹状溝13の側壁部においては窒化反応が促進されないので、凹状溝13の側壁部には窒化タングステン膜17が形成されないことになる

【0011】タングステン膜15における凹状溝13の側壁部に窒化タングステン膜17が形成されない状態で、図6(b)に示すように、全面に亘って銅膜18を堆積すると、タングステン膜15が銅膜18に対する充分なバリア性を有していないので、銅膜18はタングステン膜15における凹状溝13の側壁部を通ってシリコン酸化膜12中に拡散し、シリコン基板11上に形成されたデバイスに悪影響を与えるという問題がある

【0012】また、前述した、凹状溝の底部及び側壁部に高融点金属を堆積して金属膜を形成する工程は、凹状溝の底部及び側壁部に対するカバレッジが良好なCVD法により行なうことが好ましいが、この場合、次のような問題がある。すなわち、低抵抗な金属膜を形成するべく堆積する高融点金属の結晶成長を促進させると、金属膜の表面に凹凸ができてしまい、金属膜をプラズマ窒化処理する際に、金属膜表面の凹凸によって窒化が進む部位と遅れる部位とが発生する。このために、均一に窒化された金属窒化膜よりなるバリア層が得られないという問題もある

【0013】前記に鑑み、本発明は、凹部を有する高融点導電性材料よりなる導電膜に対してプラズマ窒化を行なうにも拘らず、該導電膜における凹部の側壁部にも確実に高融点導電性材料の窒化膜が形成されるようにすることを目的とする

【0014】

【課題を解決するための手段】本発明は、10Pa以上の圧力下において高融点導電性材料よりなる導電膜に対してプラズマ窒化を行なうと、該導電膜における凹部の側壁部にも窒素イオンが到達して該導電膜が確実に窒化されるということを見い出し、該知見に基づいて成されたものである

【0015】具体的に請求項1の発明が講じた解決手段は、埋め込み配線形成方法を、半導体基板上の絶縁膜に凹部を形成する第1の工程と、前記絶縁膜の上に高融点導電性材料を堆積することにより、該高融点導電性材料よりなり前記絶縁膜の凹部と対応する部位に凹部を有する第1の導電膜を形成する第2の工程と、10Pa以上の圧力に保たれた真空槽内に前記半導体基板を保持した状態で前記第1の導電膜の表面部をプラズマ窒化することにより、前記高融点導電性材料の窒化物よりなり前記第1の導電膜の凹部と対応する部位に凹部を有する第2の導電膜を形成する第3の工程と、前記第2の導電膜の上に配線用金属を前記第2の導電膜の凹部に前記配線用金属が埋め込まれるように堆積することにより、前記配線用金属よりなる金属膜を形成する第4の工程と、前記第1の導電膜、第2の導電膜及び金属膜における前記絶縁膜の凹部の外側に位置する部分を除去して、前記第2の導電膜の凹部内に前記配線用金属からなる埋め込み配線を形成する第5の工程とを備えている構成とするものである

【0016】請求項1の構成により、以下の現象が生じる

【0017】窒素イオンの平均自由工程λ_iは真空槽内の圧力Pに反比例するから、窒素イオンの平均自由工程λ_iは、圧力Pが1mTorrのときに10cm以上であるのに対して、圧力Pが10Pa(75mTorr)のときには1mm程度となる。従って、数mmのシース長L_{sh}を持つシース領域を通過する窒素イオンは気体分子(窒素分子)と平均数回程度衝突することになる

【0018】実際は、シース長L_{sh}と圧力Pとの間には、

$L_{sh} = bP^{-a}$ (a, b:定数、0<a<0.5) ……(1)

の関係があり、シース長L_{sh}も圧力Pが高くなるにつれて小さくなるので、シース領域における衝突回数が圧力に単純に反比例することはない

【0019】半導体基板側に陰極降下電圧V_{DC}が発生しないアノード型カップルド型プラズマ装置や、負バイアス印加を行なわないプラズマ処理装置においては、定数aは殆ど0であるため、シース長L_{sh}は圧力Pと殆ど無関係である。従って、これらのプラズマ装置を用いる場合において圧力Pが10Pa以上であると、シース領域において窒素イオンは気体分子と平均数回程度衝突するので、半導体基板に対して垂直方向から衝突しない(つまり斜め方向から衝突する)窒素イオンが多数発生する。この場合、半導体基板に対して斜め方向から入射する窒素イオンは凹部の底部のみならず凹部の側壁にも衝突するので、凹部の側壁に形成された高融点導電性材料よりなる第1の導電膜の窒化反応が促進される

【0020】尚、平均衝突回数が3回以上であれば、確率的には、大部分の窒素イオンは半導体基板に到達するまでに少なくとも1回は気体分子と衝突する

【0021】請求項2の発明は、請求項1の構成に、前記第3の工程は、50Pa以上の圧力に保たれた前記真空槽内に前記半導体基板を保持して前記第1の導電膜の表面部をプラズマ窒化する工程を含む構成を付加するものである

【0022】請求項2の構成により、以下のような現象が起きる。すなわち、真空槽内が50Pa以上の圧力に保たれているため、シース領域において窒素イオンは気体分子と平均10回以上衝突するので、窒素イオンは半導体基板に衝突する直前に気体分子と衝突する割合が極めて高くなる。このため、窒素イオンはシース領域において半導体基板に対して垂直な方向に加速されているため、ある程度の大きさの基板垂直方向のエネルギーを持った窒素イオンが半導体基板に衝突する直前に気体分子と衝突すると、窒素イオンの半導体基板に対して平行な方向のエネルギーは増加する。従って、半導体基板に対して浅い角度で入射する窒素イオンの割合が増加する

【0023】請求項3の発明は、請求項1の構成に、前記第4の工程における配線用金属は銅又は銅合金であるという限定を付加するものである

【0024】請求項4の発明は、請求項1の構成に、前記第2の工程における高融点導電性材料はチタン、タンタル又はタングステンであるという限定を付加するものである

【0025】請求項5の発明は、請求項1の構成に、前記第3の工程は、前記半導体基板をアース電位又は正電位に保持した状態でプラズマ窒化を行なう工程を含む構成を付加するものである

【0026】請求項5の構成により、以下の現象が起きる。すなわち、半導体基板側に陰極降下電圧V_{DC}が発生するカソードカップルド型プラズマ装置や、基板側に負バイアスを印加するプラズマ処理装置においては、プラズマ電位以上の電位によって窒素イオンが加速されるプラズマ窒化工程において、窒素イオンが窒素分子と衝突して散乱される角度(反跳角度)にはイオンエネルギー依存性があり、イオンエネルギーが小さいほど広い角度に散乱される。従って、前述したプラズマ電位以上の電位によって窒素イオンが加速されるプラズマ装置においては、窒素イオンが気体分子と衝突しても、凹部の側壁部の第1の導電膜を窒化できるような浅い角度で半導体基板に入射することは難しい。ところが、半導体基板をアース電位又は正電位に保持した状態でプラズマ窒化を行なうと、窒素イオンはプラズマ電位のみによって加速されることになるため、窒素イオンの反跳角度が拡がるので、窒素イオンは半導体基板に対して浅い角度で入射することになる

【0027】請求項6の発明は、請求項1の構成に、前記第2の工程は、CVD法により前記金属を堆積する工程を含むという構成を付加するものである

【0028】請求項6の構成により、第1の導電膜を形成する工程はCVD法により行なわれるので、絶縁膜の凹部の底部及び側壁部にに対して優れたカバレッジを持つ第1の導電膜を形成することができる

【0029】請求項7の発明は、請求項6の構成に、前記第2の工程は、前記高融点導電性材料の結晶化が抑えられる温度領域で該高融点導電性材料を堆積することにより、該高融点導電性材料の少なくとも一部がアモルファスな状態で前記第1の導電膜を形成する工程を含む構成を付加するものである

【0030】請求項7の構成により、第1の導電膜を構成する高融点導電性材料の結晶化が抑えられる温度領域で該高融点導電性材料を堆積することにより、該高融点導電性材料の少なくとも一部がアモルファスな状態で第1の導電膜を形成するため、第1の導電膜の表面に凹凸ができにくいので、第1の導電膜の表面部に対してプラズマ窒化処理を行なって第2の導電膜を形成する際に、第1の導電膜に対する窒化がほぼ均一な速度で進む

【0031】

【発明の実施の形態】図1及び図2は本発明の一実施形態に係る埋め込み配線形成方法の工程順断面図を示している

【0032】まず、図1(a)に示すように、シリコン基板11の上にプラズマCVD法により絶縁膜としての膜厚1.5μmのシリコン酸化膜12を堆積した後、シリコン酸化膜12に深さ600nmの配線パターンの凹状溝13を形成する

【0033】次に、図1(b)に示すように、シリコン酸化膜12の上にスパッタ法により密着層としての膜厚30nmのチタン膜14を堆積した後、チタン膜14の上にWF_6ガスを用いる熱CVD法により、高融点導電性材料からなる第1の導電膜としての膜厚50nmのタングステン膜15を堆積する。一般的には、熱CVD法によりタングステン膜を形成する際の処理温度としては、結晶成長が十分に進み、比抵抗の小さい膜を堆積できる450℃程度が採用される。ところが、結晶成長が十分に進むと、タングステン膜15の表面には数十nm

の凹凸が生じてしまい、凹状溝１２の開口部からみると凹状溝１２の側壁における凸部の下側に影ができてしまう　側壁における凸部の影になる領域には、後述するプラズマ窒化処理の際にタングステン膜１５の窒化が十分に進まないので、結晶成長を抑制するために３５０Ｃ程度の温度で熱ＣＶＤ法を行なって、表面が平滑なタングステン膜１５を堆積することが好ましい

【００３４】次に、図４に示すようなアノードカップリング型プラズマ装置を用いて、図１（ｃ）に示すように、窒素イオン１６をタングステン膜１５の表面に到達させて、タングステン膜１５の表面に銅に対するバリア層となる第２の導電膜としての窒化タングステン膜１７を形成する　図４において、２０は真空槽、２１は真空槽２０内に設けられておりシリコン基板１１を保持するアノード電極となる試料台であって、該試料台２１は接地されている　また、図４において、２２は試料台２１に対向するように設けられたカソード電極となる対向電極であって、該対向電極２２には高周波電力が印加される　これにより、試料台２１と対向電極２２との間のプラズマ領域２３においてプラズマが発生する　このようなアノードカップリング型プラズマ装置を用いて窒化タングステン膜１７を形成すると、シリコン基板１１に陰極降下電圧が発生しないため、前記の（１）式において、定数 a が殆ど０になるので、シース長 L_{sh} は圧力Pとは無関係になる

【００３５】以下、タングステン膜１５の表面に窒化タングステン膜１７を形成する処理条件について説明する

【００３６】窒素イオン１６がシリコン基板１１に対して斜め方向に入射するような処理条件としては、例えば

ガスの種類	：N_2
ガス流量	：１００ｓｃｃｍ
圧力	：１０Ｐａ（７５ｍＴｏｒｒ）
ＲＦパワー	：５００Ｗ
試料台温度	：２５Ｃ
処理時間	：６０ｓｅｃ

が挙げられる

【００３７】真空槽２０の内部圧力が１０Ｐａの場合には、窒素イオン１６の平均自由工程は１ｍｍ程度であるので、図３に示すように、シース長が約３ｍｍのシース領域を通過する窒素イオン１６は窒素分子と平均３回の頻度で衝突する　また、窒素イオン１６の平均衝突回数が３回以上であれば、ほぼすべての窒素イオン１６がシリコン基板１１に到達するまでに少なくとも１回は窒素分子を衝突することになる　このように、真空槽２０の内部圧力を１０Ｐａ以上にすると、シース領域において、窒素イオン１６は確実に窒素分子と衝突するため、ほぼすべての窒素イオン１６が、シリコン基板１１に対して斜め方向から入射し、タングステン膜１５における凹状溝１３の底部のみならず側壁部にも到達するようになるので、タングステン膜１５における凹状溝１３の側壁部においても窒化反応が促進される

【００３８】ところで、窒素イオン１６はシース領域において加速されるため、シリコン基板１１に到達する直前においては、シリコン基板１１に対して垂直な方向のエネルギーが大きくなっている　従って、窒素イオン１６がシリコン基板１１に到達する直前に窒素分子と衝突することが好ましい　このためには、窒素イオン１６のシース領域における窒素分子との平均衝突回数は１０回以上であることが好ましく、このような処理圧力は５０Ｐａ（３７５ｍＴｏｒｒ）以上である

【００３９】尚、処理圧力を１００Ｐａ以上にすると、シリコン基板１１に対して浅い角度で入射する窒素イオン１６の割合が急激に増加するため、タングステン膜１５の凹状溝１３においては、側壁部を含むすべての面において均一に窒化タングステン膜１７を形成することが可能になるので、より効果的である

【００４０】また、前記実施形態においては、イオンエネルギーを必要以上に大きくしないアノードカップリング型プラズマ装置を用いているため、窒素イオン１６の反跳角度が大きくなり、窒素イオン１６はシリコン基板１１に対してより斜め方向に入射することができる

【００４１】プラズマ窒化処理において、前述した処理装置及び処理条件を用いるため、３５０Ｃ程度の低温における熱ＣＶＤ法により表面が平滑なタングステン膜１５が堆積されることと、窒素イオン１６がシリコン基板１１に対して斜め方向から入射してタングステン膜１５における凹状溝１３の側壁に確実に衝突することとが合わさって、凹状溝１３の側壁に窒化タングステン膜１７を確実且つ均一に形成することができる

【００４２】尚、前記実施形態においては、窒化タングステン膜１７を形成する際の圧力として、１０Ｐａを用いたが、圧力を５０Ｐａ又は１００Ｐａ程度にすると、シリコン基板１１に対して浅い角度で入射する窒素イオン１６の割合が増加するので、凹状溝１３の側壁に窒化タングステン膜１７をより均一に形成することができる

【００４３】また、前記実施形態においては、前述のようにアノードカップリング型プラズマ装置を用いてタングステン膜１５のプラズマ窒化を行なったが、バイアス無印加のＩＣＰ（容量結合型プラズマ）や、マイクロ波プラズマ発生装置等を用いても同等の効果が得られる　シリコン基板１１側に陰極降下電圧 V_{DC} が発生するカソードカップルド型プラズマ装置や、シリコン基板１１側に負バイアスを印加するプラズマ処理装置は、反跳角度のイオンエネルギー依存性により、窒素イオン１６の持つシリコン基板１１に垂直な方向のエネルギーが大きくなってしまうので、避けることが好ましい　すなわち、試料台２１を接地する等して、プラズマ電位のみによってイオンを加速させることが好ましい

【００４４】次に、図２（ａ）に示すように、スパッタ法により膜厚８００ｎｍの金属膜としての銅膜１８を全面に堆積した後、銅膜１８に対して水素雰囲気中で４００Ｃの熱処理を行なって、銅膜１８を凹状溝１３の内部に流し込む

【００４５】次に、化学機械研磨によって、図２（ｂ）に示すように、凹状溝１３の外部に堆積されているチタン膜１４、タングステン膜１５、窒化タングステン膜１７及び銅膜１８を除去する　その後、既知の方法によりシリコン窒化膜等を含む層間絶縁膜を堆積した後、該層間絶縁膜の上に配線層を形成することにより、多層配線を形成する

【００４６】図５は、プラズマ窒化プロセスにおける処理圧力Ｐと、タングステン膜１５中に拡散した銅濃度との関係を示しており、処理圧力が１０Ｐａ以上になると、銅濃度が著しく低下することが分かる　これにより、タングステン膜１５における凹状溝１３の底部及び側壁部に窒化タングステン膜１７が確実に形成されていることを確認できた　また、図５から、処理圧力が１００Ｐａ以上になると、銅の拡散量を４桁程度抑制でき、タングステン膜１５における凹状溝１３の底部及び側壁部に窒化タングステン膜１７がより確実に形成されていることが分かる

【００４７】以上のように、本実施形態においては、プラズマ窒化プロセスにおいて、前記の処理装置及び処理条件を用いるため、窒素イオン１６はシリコン基板１１に対して確実に斜め方向から入射し、タングステン膜１５における凹状溝１３の側壁部に効率良く到達するので、該側壁部においても窒化タングステン膜１７を確実に形成することができる　これにより、銅膜１８のシリコン酸化膜１２への拡散が抑制され、配線抵抗が低くトランジスタ等の素子に悪影響を及ぼさない埋め込み銅配線を形成することが可能になる

【００４８】尚、前記実施形態においては、高融点導電性材料としてタングステンを用い、タングステン膜１５に対するプラズマ窒化によりバリア層となる窒化タングステン膜１７を形成したが、窒化タングステン膜１７に代えて、チタン膜やタンタル膜等の他の高融点金属膜を用いることができ、これら他の高融点金属膜に対するプラズマ窒化によって形成される窒化チタン膜や窒化タンタル膜等のバリア層を用いることもできる　また、高融点導電性材料として窒化チタン等を用い、該窒化チタン等よりなる高融点導電膜に対するプラズマ窒化によって形成されるバリア性が向上したバリア層を窒化タングステン膜１７に代えて用いることもできる

【００４９】また、前記実施形態においては、タングステン膜１５のシリコン酸化膜１２に対する密着性を向上させるため、シリコン酸化膜１２の上に密着層としてのチタン膜１４を堆積したが、バリア層として窒化チタン膜を形成する場合には前記の密着層はなくてもよい

【００５０】また、前記実施形態においては、配線用金属としては銅を用いたが、銅に代えて、銅合金、金又は銀を用いてよい

【００５１】

【発明の効果】請求項１の発明に係る埋め込み配線形成方法によると、真空槽内を１０Ｐａ以上の圧力に保持した状態で第１の導電膜の表面部をプラズマ窒化するため、ほぼすべての窒素イオンがシース領域において窒素分子と最低１回衝突するので、試料台に対して垂直方向に進む窒素イオンのうちのほぼすべての窒素イオンが進む方向を変えられ、半導体基板に対して斜め方向から入射する　このため、第２の導電膜の凹部内に入射する窒素イオンのうちの一部は凹部の側壁部に確実に到達するので、第２の導電膜における凹部の側壁部には確実に高融点導電性材料の窒化膜が形成され、これにより、配線用金属の絶縁膜への拡散を防止することができる　また、絶縁膜がシリコン酸化膜の場合には配線用金属の酸化を防止することもできる

【００５２】請求項２の発明に係る埋め込み配線形成方法によると、真空槽内を５０Ｐａ以上の圧力に保持した状態で第１の導電膜の表面部をプラズマ窒化するため、シース領域において窒素イオンは窒素分子と平均１０回以上衝突するので、窒素イオンは試料台に対して平行な方向のエネルギーが増大すると共に半導体基板に到達する直前に窒素分子と衝突する割合も増大する　このため、窒素イオンは半導体基板に対して一層大きな角度をもって入射するので、第２の導電膜の凹部の壁部に到達する窒素イオンの割合が増大し、第２の導電膜における凹部の側壁部は一層確実に窒化される

【００５３】請求項３の発明に係る埋め込み配線形成方法によると、銅又は銅合金からなる配線用金属の絶縁膜中への拡散を防止することができる

【００５４】請求項４の発明に係る埋め込み配線形成方法によると、チタン、タンタル又はタングステンの窒化物からなるバリア層を形成することができる

【００５５】請求項５の発明に係る埋め込み配線形成方法によると、半導体基板をアース電位又は正電位に保持した状態でプラズマ窒化を行なうため、窒素イオンは半導体基板に対してより浅い角度で入射するので、より均一な高融点導電性材料の窒化物よりなる第２の導電膜を形成することができる

【００５６】請求項６の発明に係る埋め込み配線形成方法によると、第１の導電膜を形成する工程はＣＶＤ法により行なわれるので、優れたカバレッジを持つ第１の導電膜を絶縁膜の凹部に形成することができる

【００５７】請求項７の発明に係る埋め込み配線形成方法によると、第１の導電膜の表面に凹凸ができにくいため、第１の導電膜に対するプラズマ窒化工程において、第１の導電膜に対する窒化がほぼ均一な速度で進むので、高融点導電性材料の窒化物からなるより均一な第２

の導電膜を形成することができる

【図面の簡単な説明】

【図１】本発明の一実施形態に係る埋め込み配線形成方法の各工程を示す断面図である

【図２】本発明の一実施形態に係る埋め込み配線形成方法の各工程を示す断面図である

【図３】本発明の一実施形態に係る埋め込み配線形成方法のプラズマ窒化工程において窒素イオンが窒素分子と衝突する状態を示す概念図である

【図４】本発明の一実施形態に係る埋め込み配線形成方法に用いるアノードカップリング型プラズマ装置の概略構成図である

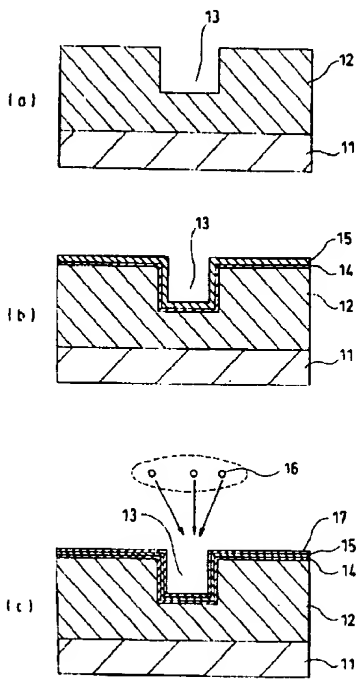
【図５】本発明の一実施形態に係る埋め込み配線形成方法のプラズマ窒化工程における処理圧力Ｐとタングステン膜中に拡散した銅濃度との関係を示す特性図である

【図６】従来の埋め込み配線形成方法の問題点を説明する断面図である

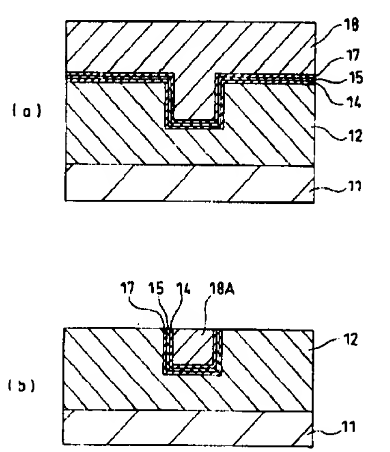
【符号の説明】

１１　シリコン基板（半導体基板）
１２　シリコン酸化膜（絶縁膜）
１３　溝状溝（凹部）
１４　チタン膜
１５　タングステン膜（第１の導電膜）
１６　窒素イオン
１７　窒化タングステン膜（第２の導電膜）
１８　銅膜（金属膜）
２０　真空槽
２１　試料台
２２　対向電極
２３　プラズマ領域

【図１】



【図２】



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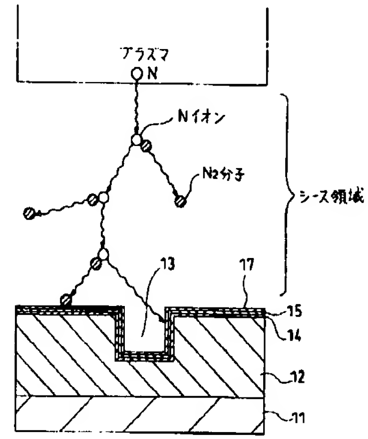

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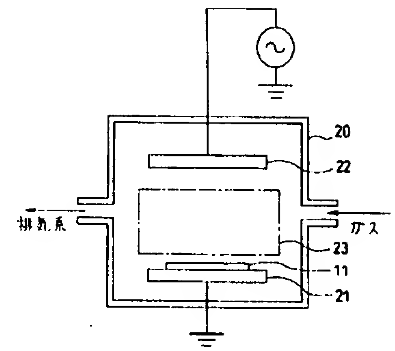

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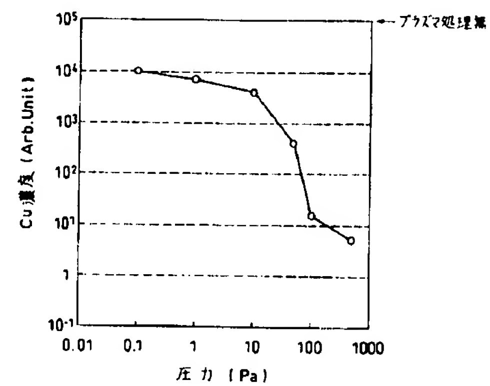
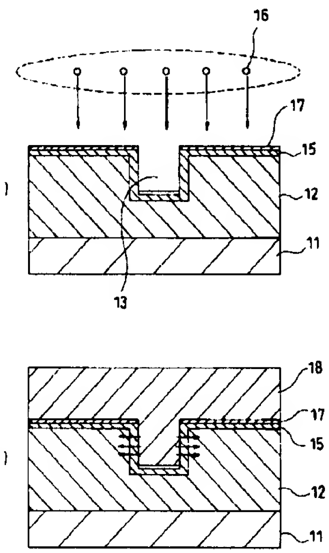


【図6】

(c)
(d)



PATENT ABSTRACTS OF JAPAN

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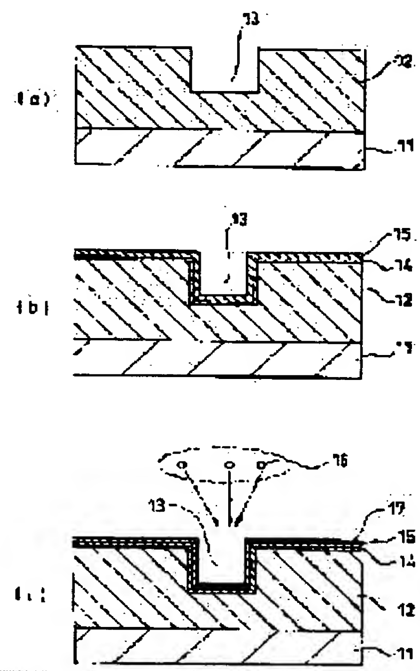
(54) METHOD OF FORMING BURIED WIRING

(57)Abstract:
PROBLEM TO BE SOLVED: To surely form a nitride film of high fusing point conductive material also at the sidewall of the recess of a high fusing point conductive material film, though plasma nitrification is performed to the high fusing point conductive material film having a recess.
SOLUTION: A silicon substrate 11 where a silicon oxide film 12 having a recessed groove 13 is made on the surface is retained on a sample provided within a vacuum container, and then a titanium film 14 and a tungsten film 15 are stacked in order on the silicon oxide film 12. In condition that the interior of the vacuum container is kept at a pressure of 10Pa, the surface of the tungsten film 15 is nitrided by plasma to form a tungsten nitride film 17. On the tungsten nitride film 17, a copper film is accumulated on the tungsten nitride film 17, and then the titanium film 14, the tungsten film 15, and the tungsten nitride film 17, and the section positioned outside the recessed groove 13 in the copper film are removed to form a buried wiring consisting of copper.



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CLAIMS

[Claim(s)]

[Claim 1] The embedding wiring formation method characterized by providing the following. The 1st process which forms a crevice in the insulator layer on a semiconductor substrate. The 2nd process which forms the 1st electric conduction film which has a crevice in the part which consists of this high-melting point conductivity material, and corresponds with the crevice of the aforementioned insulator layer by depositing high-melting point conductivity material on the aforementioned insulator layer. The 3rd process which forms the 2nd electric conduction film which has a crevice in the part which consists of a nitride of the aforementioned high-melting point conductivity material, and corresponds with the crevice of the electric conduction film of the above 1st by holding the aforementioned semiconductor substrate and carrying out the plasma nitriding of the surface section of the electric conduction film of the above 1st into the vacuum tub maintained at the pressure of 10Pa or more. the electric conduction film top of the above 2nd -- wiring -- public funds -- a group -- the crevice of the electric conduction film of the above 2nd -- the aforementioned wiring -- public funds -- by depositing so that a group may be embedded the aforementioned wiring -- public funds -- the portion located in the outside of the crevice of the aforementioned insulator layer in the 4th process which forms the metal membrane which consists of a group, the electric conduction film of the above 1st, the 2nd electric conduction film, and a metal membrane -- removing -- the inside of the crevice of the electric conduction film of the above 2nd -- the aforementioned wiring -- public funds -- the 5th process which consists of a group and which embeds and forms wiring

[Claim 2] The 3rd process of the above is the embedding wiring formation method according to claim 1 characterized by including the process which holds the aforementioned semiconductor substrate and carries out the plasma nitriding of the surface section of the electric conduction film of the above 1st into the aforementioned vacuum tub maintained at the pressure of 50Pa or more.

[Claim 3] the wiring in the 4th process of the above -- public funds -- the embedding wiring formation method according to claim 1 characterized by a group being copper or a copper alloy

[Claim 4] The high-melting point conductivity material in the 2nd process of the above is the embedding wiring formation method according to claim 1 characterized by being titanium, a tantalum, or a tungsten.

[Claim 5] The 3rd process of the above is the embedding wiring formation method according to claim 1 characterized for including the process which performs plasma nitriding where the aforementioned semiconductor substrate is held to ground potential or right potential by things.

[Claim 6] The 2nd process of the above is the embedding wiring formation method according to claim 1 characterized by including the process which deposits the aforementioned high-melting point conductivity material by CVD.

[Claim 7] The 2nd process of the above is the embedding wiring formation method according to claim 6 characterized by including the process in which a part of this high-melting point conductivity material [at least] forms the electric conduction film of the above 1st in the amorphous state by depositing this high-melting point conductivity material in the temperature field in which crystallization of the aforementioned high-melting point conductivity material is suppressed.

[Translation done.]

DETAILED DESCRIPTION

[Detailed Description of the Invention]
[0001]
[The technical field to which invention belongs] crevices, such as a concave slot where this invention was formed in the insulator layer in the manufacturing process of semiconductor integrated circuit equipment etc., -- wiring -- public funds -- the method of embedding and embedding a group and forming wiring -- being related -- especially -- wiring -- public funds -- it is related with the technology of preventing the situation which a group oxidizes or is diffused in an insulator layer
[0002]
[Description of the Prior Art] the wiring used for semiconductor integrated circuit equipment etc. now -- public funds -- the copper or the copper alloy resistance excels [copper alloy] in electromigration resistance low as compared with the aluminium alloy although an aluminium alloy is used in many cases as a group -- wiring of the next generation -- public funds -- promising ** is carried out as a group
[0003] The biggest technical problem to utilization of the copper wiring which consists of copper or a copper alloy is the processability over prevention of oxidization of copper wiring, prevention of diffusion into the insulating layer of copper wiring, and a copper film. Especially the copper or the copper alloy that constitutes copper wiring is SiO2 used as a layer insulation film. In oxidizing with a film ****, it is SiO2. Since it is easy to be spread in a film, there is a possibility of having a bad influence on devices, such as a transistor currently formed in the bottom of a layer insulation film. Then, forming various kinds of barrier layers between copper wiring and a layer insulation film is proposed.
[0004] N2 [as opposed to / a Cu-Ti alloy / in JP,02-240920,A] under the temperature of 800 degrees C The method of preventing copper oxidization and copper diffusion is proposed by forming the barrier layer which performs annealing and consists of a TiN film.
[0005] Moreover, the method of forming the barrier layer which performs the plasma nitriding by the efficient consumer response plasma method to JP,06-275623,A, "Diffusion Barrier Properties of Transition Metals and Their Nitrides for Cu Interconnections"T.Nakao et.al., and VMIC (1994) to W film, and is set to them from a nitriding tungsten film is proposed.
[0006]
[Problem(s) to be Solved by the Invention] By the way, N2 [like the former method] under the temperature of 600 degrees C or less although it is necessary to hold down the temperature of heat treatment to a barrier layer to 600 degrees C or less in order to suppress oxidization and diffusion of a lower layer of copper wiring, when forming multilevel-metal wiring using the copper wiring which consists of copper or a copper alloy A TiN film cannot be formed in annealing. N2 [on the other hand] under the temperature of about 800 degrees C If a TiN film is formed by annealing, oxidization of lower layer copper wiring and the problem of diffusion will occur. Therefore, N2 The formation of a barrier layer and the adoption of copper wiring by annealing have the problem of being hard to be compatible.
[0007] Since the latter method can form a uniform barrier layer by low temperature and the problem of oxidization and diffusion of a lower layer of copper wiring does not arise, the formation of a barrier layer and the adoption of copper wiring by plasma nitriding are compatible. However, it is very difficult copper unlike aluminum, to perform dry etching to a copper film, since the halogenated compound is nonvolatile, and to form copper wiring.
[0008] Then, after forming a concave slot in the wiring formation field in an insulator layer, a copper film is formed so that the whole surface may be covered, copper may be deposited and copper may be embedded in a concave slot, and the method of embedding and forming wiring which removes the portion of the outside of the concave slot in a copper film, and consists of copper is proposed after that.
[0009] By the way, when forming copper wiring by the embedding wiring formation method, you have to form a barrier layer not only in the pars basilaris ossis occipitalis of a concave slot but in the side-attachment-wall section. In JP,06-275623,A, as mentioned above, after depositing a metal on the pars basilaris ossis occipitalis and the side-attachment-wall section of a concave slot and forming a metal membrane, by performing the plasma nitriding by the efficient consumer response plasma method to this metal membrane, the barrier layer which consists of a nitride of the aforementioned metal is formed, and the processing pressure force at this time is set to 1mTorr.
[0010] However, there is a problem as shown in drawing 6 (a) and (b) in the conventional method of forming the barrier layer which performs plasma nitriding in 1mTorr and consists of a metaled nitride. Drawing 6 (a) forms the concave slot 13 in this silicon oxide 12, after depositing a silicon oxide 12 on a silicon substrate 11, next after it covers the whole surface and deposits the tungsten film 15 on a silicon oxide 12, it shows the process which forms the nitriding tungsten film 17 in the front face of the tungsten film 15 by plasma nitriding. In this case, possibility that nitrogen ion will collide with a nitrogen content child in a sheath field since the average free process of the nitrogen ion in 1mTorr is 10cm or more and it is quite large compared with the sheath length (about 3mm) of the sheath field between a plasma generating field and a silicon substrate is a low very much. For this reason, as shown in drawing 6 (a), incidence of the nitrogen ion 16 is carried out from an almost perpendicular direction to a silicon substrate 11. Therefore, since the nitrogen ion 16 hardly reaches the side-attachment-wall section of the concave slot 13 in the tungsten film 15 and a nitriding reaction is not promoted in the side-attachment-wall section of the concave slot 13 of the tungsten film 15, the nitriding tungsten film 17 will be formed in the side-attachment-wall section of the concave slot 13.
[0011] In the state where the nitriding tungsten film 17 is not formed in the side-attachment-wall section of the concave slot 13 in the tungsten film 15 If the whole surface is covered and a copper film 18 is deposited, as shown in drawing 6 (b), since the tungsten film 15 does not have sufficient barrier nature to a copper film 18 A copper film 18 is diffused in a silicon oxide 12 through the side-attachment-wall section of the concave slot 13 in the tungsten film 15, and has the problem of

having a bad influence on the device formed on the silicon substrate 11.

[0012] Moreover, although it is desirable that the coverage to the pars basilaris ossis occipitalis and the side-attachment-wall section of a concave slot carries out by good CVD as for the process which deposits a refractory metal on the pars basilaris ossis occipitalis and the side-attachment-wall section of the concave slot mentioned above, and forms a metal membrane, there are the following problems in this case. namely, -- low -- if the crystal growth of the refractory metal deposited to form a metal membrane [****] is promoted, in case irregularity will be made on on the surface of a metal membrane and plasma nitriding treatment of the metal membrane will be carried out, the part to which nitriding progresses with the irregularity on the front face of a metal membrane, and an overdue part occur For this reason, there is also a problem that the barrier layer which consists of a metal nitride nitrided uniformly is not obtained.

[0013] In spite of performing plasma nitriding to the electric conduction film which consists of high-melting point conductivity material into which this invention has a crevice in view of the above, it aims at the nitride of high-melting point conductivity material being certainly formed also in the side-attachment-wall section of the crevice in this electric conduction film.

[0014]

[Means for Solving the Problem] If plasma nitriding is performed to the electric conduction film which becomes the bottom of the pressure of 10Pa or more from high-melting point conductivity material, this invention will find out that nitrogen ion also reaches the side-attachment-wall section of the crevice in this electric conduction film, and this electric conduction film is nitrided certainly, and will constitute it based on this knowledge.

[0015] The solution means which invention of a claim 1 provided concretely The 1st process which forms a crevice in the insulator layer on a semiconductor substrate for the embedding wiring formation method, and by depositing high-melting point conductivity material on the aforementioned insulator layer The 2nd process which forms the 1st electric conduction film which has a crevice in the part which consists of this high-melting point conductivity material, and corresponds with the crevice of the aforementioned insulator layer, By carrying out the plasma nitriding of the surface section of the electric conduction film of the above 1st, where the aforementioned semiconductor substrate is held in the vacuum tub maintained at the pressure of 10Pa or more The 3rd process which forms the 2nd electric conduction film which has a crevice in the part which consists of a nitride of the aforementioned high-melting point conductivity material, and corresponds with the crevice of the electric conduction film of the above 1st, the electric conduction film top of the above 2nd -- wiring -- public funds -- a group -- the crevice of the electric conduction film of the above 2nd -- the aforementioned wiring -- public funds -- by depositing so that a group may be embedded The portion located in the outside of the crevice of the aforementioned insulator layer in the 4th process which forms the metal membrane which consists of the aforementioned metal for wiring, the electric conduction film of the above 1st, the 2nd electric conduction film, and a metal membrane is removed. the inside of the crevice of the electric conduction film of the above 2nd -- the aforementioned wiring -- public funds -- it considers as composition equipped with the 5th process which consists of a group and which embeds and forms wiring

[0016] The following phenomena arise by composition of a claim 1.

[0017] Average free process lambdai of nitrogen ion Since it is in inverse proportion to the pressure P in a vacuum tub, it is average free process lambdai of nitrogen ion. To being 10cm or more, when a pressure P is 1mTorr, when a pressure P is 10Pa (75mTorr), it is set to about 1mm. Therefore, the nitrogen ion which passes through a sheath field with the several mm sheath length Lsh will collide with a gas molecule (nitrogen content child) about several [an average of] times.

[0018] In practice, between the sheath length Lsh and a pressure P, it is Lsh=bP-a (a, b:constant, 0< a<0.5).... There is a relation of (1) and the sheath length Lsh is not simply [since it becomes small as it becomes high / the number of times of a collision in a sheath field] in inverse proportion for a pressure P to a pressure, either.

[0019] In the anode type KAPPURUDO type plasma equipment which the cathode drop voltage VDC does not generate in a semiconductor substrate side, and the plasma treatment equipment which does not perform negative bias impression, since most constants a are 0, its sheath length Lsh is almost unrelated to a pressure P. Therefore, since nitrogen ion collides that a pressure P is 10Pa or more with a gas molecule about several [an average of] times in a sheath field when using these plasma equipments, many nitrogen (that is, it collides from across) ion which does not collide perpendicularly to a semiconductor substrate occurs. In this case, since the nitrogen ion which carries out incidence from across to a semiconductor substrate collides not only with the pars basilaris ossis occipitalis of a crevice but with the side attachment wall of a crevice, the nitriding reaction of the 1st electric conduction film which consists of high-melting point conductivity material formed in the side attachment wall of a crevice is promoted.

[0020] In addition, probable, if mean collisional frequency is 3 times or more, by the time most nitrogen ion reaches a semiconductor substrate, it will collide with a gas molecule once [at least].

[0021] Composition including the process which holds the aforementioned semiconductor substrate and carries out the plasma nitriding of the surface section of the electric conduction film of the above 1st is added in the aforementioned vacuum tub by which invention of a claim 2 was maintained at the composition of a claim 1, and the 3rd process of the above was maintained at the pressure of 50Pa or more.

[0022] The following phenomena occur by composition of a claim 2. That is, since the inside of a vacuum tub is held at the pressure of 50Pa or more and nitrogen ion collides with a gas molecule an average of 10 times or more in a sheath field, as for nitrogen ion, the rate which collides with a gas molecule just before colliding with a semiconductor substrate becomes very high. For this reason, although nitrogen ion is accelerated in the perpendicular direction to the semiconductor substrate in the sheath field, if it collides with a gas molecule just before nitrogen ion with the energy of the substrate perpendicular direction of a certain amount of size collides with a semiconductor substrate, the energy of an parallel direction will increase to the semiconductor substrate of nitrogen ion. Therefore, the rate of the nitrogen ion which carries out incidence at a shallow angle to a semiconductor substrate increases.

[0023] wiring [in / the 4th process of the above / to the composition of a claim 1 / in invention of a claim 3] -- public funds -- a group adds limitation that they are copper or a copper alloy

[0024] Invention of a claim 4 adds limitation that the high-melting point conductivity material in the 2nd process of the above is titanium, a tantalum, or a tungsten to the composition of a claim 1.

[0025] The composition in which invention of a claim 5 includes the process which carries out plasma nitriding to the composition of a claim 1 after the 3rd process of the above has held the aforementioned semiconductor substrate to ground potential or right potential is added.

[0026] The following phenomena occur by composition of a claim 5. That is, in the cathode KAPPURUDO type plasma equipment which the cathode drop voltage VDC generates in a semiconductor substrate side, and the plasma treatment equipment which impresses negative bias to a substrate side, nitrogen ion is accelerated with the potential more than plasma potential. In a plasma nitriding process, there is an ion-energy dependency in the angle (recoil angle) on which nitrogen ion collides with a nitrogen content child, and is scattered, and it is scattered on a latus angle, so that an ion energy is small. Therefore, even if nitrogen ion collides with a gas molecule in the plasma equipment with which nitrogen ion is accelerated with the potential more than the plasma potential mentioned above, it is difficult to carry out incidence to a semiconductor substrate at the shallow angle which can nitride the 1st electric conduction film of the side-attachment-wall section of a crevice. However, if plasma nitriding is performed where a semiconductor substrate is held to ground potential or right potential, since nitrogen ion will be accelerated only with plasma potential and the recoil angle of nitrogen ion will spread, incidence of the nitrogen ion will be carried out at a shallow angle to a semiconductor substrate.
[0027] Invention of a claim 6 adds the composition that the 2nd process of the above includes the process which deposits the aforementioned metal by CVD to the composition of a claim 1.
[0028] since the process which forms the 1st electric conduction film by composition of a claim 6 is performed by CVD, the 1st electric conduction film with the coverage which resembled the pars basilaris ossis occipitalis and the side-attachment-wall section of a crevice of an insulator layer, and received and was excellent in them can be formed
[0029] Invention of a claim 7 adds composition including the process in which a part of this high-melting point conductivity material [at least] forms the electric conduction film of the above 1st in the amorphous state to the composition of a claim 6, when the 2nd process of the above deposits this high-melting point conductivity material in the temperature field in which crystallization of the aforementioned high-melting point conductivity material is suppressed.
[0030] By depositing this high-melting point conductivity material in the temperature field in which crystallization of the high-melting point conductivity material which constitutes the 1st electric conduction film is suppressed by composition of a claim 7 Since a part of this high-melting point conductivity material [at least] forms the 1st electric conduction film in the amorphous state and irregularity cannot be easily made on the front face of the 1st electric conduction film In case plasma nitriding treatment is performed to the surface section of the 1st electric conduction film and the 2nd electric conduction film is formed, the nitriding to the 1st electric conduction film progresses at an almost uniform speed.
[0031]
[Embodiments of the Invention] Drawing 1 and drawing 2 show the order cross section of a process of the embedding wiring formation method concerning 1 operation gestalt of this invention.
[0032] First, as shown in drawing 1 (a), after depositing the silicon oxide 12 of 1.5 micrometers of thickness as an insulator layer by the plasma CVD method on a silicon substrate 11, the concave slot 13 of a circuit pattern with a depth of 600nm is formed in a silicon oxide 12.
[0033] Next, it is WF_6 on the titanium film 14 as shown in drawing 1 (b). after depositing the titanium film 14 of 30nm of thickness as an adhesion layer by the spatter on a silicon oxide 12. By the heat CVD using gas, the tungsten film 15 of 50nm of thickness as 1st electric conduction film which consists of high-melting point conductivity material is deposited. Generally, as processing temperature at the time of forming a tungsten film by heat CVD, a crystal growth fully progresses and about 450 degrees C which can deposit the small film of specific resistance are adopted. However, if a crystal growth fully progresses, the irregularity of dozens of nm will arise in the front face of the tungsten film 15, and a shadow will be made to the heights bottom in the side attachment wall of the concave slot 12, in view of opening of the concave slot 12. It is desirable that perform heat CVD in the field which becomes the shadow of the heights in a side attachment wall at the temperature of about 350 degrees C in order to suppress a crystal growth. since nitriding of the tungsten film 15 does not fully progress in the case of the plasma nitriding treatment mentioned later, and a front face deposits the smooth tungsten film 15 on it.
[0034] Next, using anode distributor-shaft-coupling type plasma equipment as shown in drawing 4 , as shown in drawing 1 (c), the nitrogen ion 16 is made to arrive at the front face of the tungsten film 15, and the nitriding tungsten film 17 as 2nd electric conduction film used as the barrier layer to copper is formed in the front face of the tungsten film 15. In drawing 4 , it is a sample base used as the anode electrode which 20 is prepared in a vacuum tub, and 21 is prepared in the vacuum tub 20, and holds a silicon substrate 11, and this sample base 21 is grounded. Moreover, in drawing 4 , 22 is a counterelectrode used as the cathode electrode prepared so that the sample base 21 might be countered, and RF power is impressed to this counterelectrode 22. Thereby, plasma occurs in the plasma field 23 between the sample base 21 and a counterelectrode 22. If the nitriding tungsten film 17 is formed using such anode distributor-shaft-coupling type plasma equipment, since cathode drop voltage does not occur in a silicon substrate 11 and a constant a will almost be set to 0 in the aforementioned (1) formula, the sheath length Lsh becomes unrelated to a pressure P.
[0035] Hereafter, the processing conditions which form the nitriding tungsten film 17 in the front face of the tungsten film 15 are explained.
[0036] As processing conditions in which the nitrogen ion 16 carries out incidence in the direction of slant to a silicon substrate 11, it is the kind of gas, for example. : N2 quantity of gas flow : 100sccm pressure : 10Pa (75mTorr)
RF power : 500W sample base temperature : 25-degree-C processing time : 60sec is mentioned.
[0037] Since the average free process of the nitrogen ion 16 is about 1mm when the internal pressure of the vacuum tub 20 is 10Pa, as shown in drawing 3 , the nitrogen ion 16 to which sheath length passes through about 3mm sheath field collides with a nitrogen content child by an average of 3 times of frequency. Moreover, if the mean collisional frequency of the nitrogen ion 16 is 3 times or more, by the time almost all the nitrogen ion 16 reaches a silicon substrate 11, a nitrogen content child will be collided once [at least]. Thus, if the internal pressure of the vacuum tub 20 is set to 10Pa or more, in order that the nitrogen ion 16 may collide with a nitrogen content child certainly in a sheath field, Since almost all the nitrogen ion 16 carries out incidence from across to a silicon substrate 11 and comes to reach not only the pars basilaris ossis occipitalis of the concave slot 13 in the tungsten film 15 but the side-attachment-wall section, a nitriding reaction is promoted also in the side-attachment-wall section of the concave slot 13 in the tungsten film 15.
[0038] By the way, since the nitrogen ion 16 is accelerated in a sheath field, just before reaching a silicon substrate 11, the energy of a perpendicular direction is large to the silicon substrate 11. Therefore, it is desirable to collide with a nitrogen content child, just before the nitrogen ion 16 reaches a silicon substrate 11. As for the mean collisional frequency with the nitrogen content child in the sheath field of the nitrogen ion 16, for that, it is desirable that it is 10 times or more, and such processing pressure force is more than 50Pa (375mTorr).

[0039] In addition, if the processing pressure force is set to 100Pa or more, since the rate of the nitrogen ion 16 which carries out incidence at a shallow angle to a silicon substrate 11 will increase rapidly and it becomes possible to form the nitriding tungsten film 17 uniformly in all the fields containing the side-attachment-wall section in the concave slot 13 of the tungsten film 15, it is more effective.
[0040] Moreover, in the aforementioned operation gestalt, since the anode distributor-shaft-coupling type plasma equipment which does not make an ion energy larger than required is used, the recoil angle of the nitrogen ion 16 becomes large, and incidence of the nitrogen ion 16 can be carried out more in the direction of slant to a silicon substrate 11.
[0041] In order to use the processor and processing conditions which were mentioned above in plasma nitriding treatment, The tungsten film 15 with a smooth front face accumulates by the heat CVD in about 350-degree C low temperature, The nitrogen ion 16 can carry out incidence from across to a silicon substrate 11, it can be put together to collide with the side attachment wall of the concave slot 13 in the tungsten film 15 certainly, and the nitriding tungsten film 17 can be formed in the side attachment wall of the concave slot 13 certainly and uniformly.
[0042] In addition, in the aforementioned operation gestalt, since the rate of the nitrogen ion 16 which carries out incidence at a shallow angle to a silicon substrate 11 will increase as a pressure at the time of forming the nitriding tungsten film 17 if a pressure is set to 50Pa or about 100Pa although 10Pa was used, the nitriding tungsten film 17 can be formed more in the side attachment wall of the concave slot 13 at homogeneity.
[0043] Moreover, in the aforementioned operation gestalt, although plasma nitriding of the tungsten film 15 was performed using anode distributor-shaft-coupling type plasma equipment as mentioned above, even if it uses bias non-impressed ICP (capacity-coupling type plasma), a microwave plasma generator, etc., an equivalent effect is acquired. Since the energy of a direction perpendicular to the silicon substrate 11 which the nitrogen ion 16 has becomes large by the ion-energy dependency of a recoil angle, as for the cathode KAPPURUDO type plasma equipment which the cathode drop voltage VDC generates in a silicon-substrate 11 side, and the plasma treatment equipment which impresses negative bias to a silicon-substrate 11 side, avoiding is desirable. That is, it is desirable to carry out to ground the sample base 21 etc. and to accelerate ion only with plasma potential.
[0044] Next, as shown in drawing 2 (a), after depositing the copper film 18 as a metal membrane of 800nm of thickness on the whole surface by the spatter, 400-degree C heat treatment is performed in hydrogen atmosphere to a copper film 18, and a copper film 18 is slushed into the interior of the concave slot 13.
[0045] Next, chemical machinery polish removes the titanium film 14 deposited on the exterior of the concave slot 13, the tungsten film 15, the nitriding tungsten film 17, and a copper film 18, as shown in drawing 2 (b). Then, after depositing the layer insulation film which contains a silicon nitride etc. by the known method, a multilayer interconnection is formed by forming a wiring layer on this layer insulation film.
[0046] Drawing 5 shows the relation between the processing pressure force P in a plasma nitriding process, and the copper concentration diffused in the tungsten film 15, and when the processing pressure force is set to 10Pa or more, it turns out that copper concentration falls remarkably. Thereby, it has checked that the nitriding tungsten film 17 was certainly formed in the pars basilaris ossis occipitalis and the side-attachment-wall section of the concave slot 13 in the tungsten film 15. Moreover, when the processing pressure force is set to 100Pa or more from drawing 5 , it turns out that about 4 figures of copper diffusing capacities can be suppressed, and the nitriding tungsten film 17 is more certainly formed in the pars basilaris ossis occipitalis and the side-attachment-wall section of the concave slot 13 in the tungsten film 15.
[0047] As mentioned above, in this operation gestalt, in a plasma nitriding process, since incidence of the nitrogen ion 16 is certainly carried out from across to a silicon substrate 11 and the side-attachment-wall section of the concave slot 13 in the tungsten film 15 is efficiently reached in order to use an aforementioned processor and aforementioned processing conditions, also in this side-attachment-wall section, the nitriding tungsten film 17 can be formed certainly. Thereby, the diffusion to the silicon oxide 12 of a copper film 18 is suppressed, and the thing to which wiring resistance does not have a bad influence on elements, such as a transistor, low and for which it embeds and copper wiring is formed becomes possible.
[0048] In addition, in the aforementioned operation gestalt, although the nitriding tungsten film 17 which serves as a barrier layer by the plasma nitriding to the tungsten film 15 was formed using a tungsten as a high-melting point conductivity material, it can replace with the nitriding tungsten film 17, other high-melting point metal membranes, such as a titanium film and a tantalum film, can be used, and barrier layers formed of the plasma nitriding to a high-melting point metal membrane besides these, such as a titanium-nitride film and a tantalum-nitride film, can also be used. Moreover, the barrier layer whose barrier nature formed of the plasma nitriding to the high-melting point electric conduction film which consists of this titanium nitride etc. improved can also be replaced with and used for the nitriding tungsten film 17, using a titanium nitride etc. as a high-melting point conductivity material.
[0049] Moreover, in the aforementioned operation gestalt, although the titanium film 14 as an adhesion layer was deposited on the silicon oxide 12 in order to raise the adhesion to the silicon oxide 12 of the tungsten film 15, when forming a titanium-nitride film as a barrier layer, the aforementioned adhesion layer may not be.
[0050] moreover, the aforementioned operation gestalt -- setting -- wiring -- public funds -- although copper was used as a group, it may replace with copper and a copper alloy, gold, or silver may be used
[0051]
[Effect of the Invention] Where the inside of a vacuum tub is held in pressure of 10Pa or more, in order to carry out the plasma nitriding of the surface section of the 1st electric conduction film according to the embedding wiring formation method concerning invention of a claim 1, Since almost all nitrogen ion collides with a nitrogen content child once [at least] in a sheath field, the direction to which almost all the nitrogen ion of the nitrogen ion which progresses perpendicularly to a sample base goes can be changed, and incidence is carried out from across to a semiconductor substrate. for this reason, since the part of the nitrogen ion which carries out incidence into the crevice of the 2nd electric conduction film reaches the side-attachment-wall section of a crevice certainly, the nitride of high-melting point conductivity material forms in the side-attachment-wall section of the crevice in the 2nd electric conduction film certainly -- having -- thereby -- wiring -- public funds -- the diffusion to the insulator layer of a group can be prevented Moreover, when an insulator layer is a silicon oxide, oxidization of the metal for wiring can also be prevented.
[0052] Since nitrogen ion collides with a nitrogen content child an average of 10 times or more in a sheath field in order to carry out the plasma nitriding of the surface section of the 1st electric conduction film according to the embedding wiring formation method concerning invention of a claim 2, where the inside of a vacuum tub is held in pressure of 50Pa or more, the rate which collides with a nitrogen content child just before nitrogen ion reaches a semiconductor substrate while the

energy of an parallel direction increases to a sample base also increases. For this reason, since incidence of the nitrogen ion is carried out with a much more big angle to a semiconductor substrate, the rate of the nitrogen ion which reaches the wall of the crevice of the 2nd electric conduction film increases, and the side-attachment-wall section of the crevice in the 2nd electric conduction film is nitrided much more certainly.

[0053] the wiring which consists of copper or a copper alloy according to the embedding wiring formation method concerning invention of a claim 3 -- public funds -- diffusion into the insulator layer of a group can be prevented

[0054] According to the embedding wiring formation method concerning invention of a claim 4, the barrier layer which consists of a nitride of titanium, a tantalum, or a tungsten can be formed.

[0055] Since incidence of the nitrogen ion is carried out at a shallower angle to a semiconductor substrate in order to perform plasma nitriding according to the embedding wiring formation method concerning invention of a claim 5, where a semiconductor substrate is held to ground potential or right potential, the 2nd electric conduction film which consists of a nitride of a more uniform high-melting point conductivity material can be formed.

[0056] Since the process which forms the 1st electric conduction film is performed by CVD according to the embedding wiring formation method concerning invention of a claim 6, the 1st electric conduction film with the outstanding coverage can be formed in the crevice of an insulator layer.

[0057] Since according to the embedding wiring formation method concerning invention of a claim 7 irregularity cannot be easily made on the front face of the 1st electric conduction film and the nitriding to the 1st electric conduction film progresses at an almost uniform speed in the plasma nitriding process over the 1st electric conduction film, the 2nd uniform electric conduction film can be formed rather than it consists of a nitride of high-melting point conductivity material.

[Translation done.]

DESCRIPTION OF DRAWINGS

[Brief Description of the Drawings]
[Drawing 1] It is the cross section showing each process of the embedding wiring formation method concerning 1 operation gestalt of this invention.
[Drawing 2] It is the cross section showing each process of the embedding wiring formation method concerning 1 operation gestalt of this invention.
[Drawing 3] In the plasma nitriding process of the embedding wiring formation method concerning 1 operation gestalt of this invention, nitrogen ion is the conceptual diagram showing the state of colliding with a nitrogen content child.
[Drawing 4] It is the outline block diagram of the anode distributor-shaft-coupling type plasma equipment used for the embedding wiring formation method concerning 1 operation gestalt of this invention.
[Drawing 5] It is the property view showing the relation between the processing pressure force P in the plasma nitriding process of the embedding wiring formation method concerning 1 operation gestalt of this invention, and the copper concentration diffused in the tungsten film.
[Drawing 6] It is a cross section explaining the trouble of the conventional embedding wiring formation method.
[Description of Notations]
11 Silicon Substrate (Semiconductor Substrate)
12 Silicon Oxide (Insulator Layer)
13 Concave Slot (Crevice)
14 Titanium Film
15 Tungsten Film (1st Electric Conduction Film)
16 Nitrogen Ion
17 Nitriding Tungsten Film (2nd Electric Conduction Film)
18 Copper Film (Metal Membrane)
20 Vacuum Tub
21 Sample Base
22 Counterelectrode
23 Plasma Field

[Translation done.]

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[Procedure amendment 1]
[Document to be Amended] Specification.
[Item(s) to be Amended] Claim.
[Method of Amendment] Change.
[Proposed Amendment]
[Claim(s)]
[Claim 1] The 1st process which forms a crevice in the insulator layer on a semiconductor substrate,
The 2nd process which forms the 1st electric conduction film which has a crevice in the part which consists of this high-melting point conductivity material, and corresponds with the crevice of the aforementioned insulator layer by depositing high-melting point conductivity material on the aforementioned insulator layer,
The 3rd process which forms the 2nd electric conduction film which has a crevice in the part which consists of a nitride of the aforementioned high-melting point conductivity material, and corresponds with the crevice of the electric conduction film of the above 1st by holding the aforementioned semiconductor substrate and carrying out the plasma nitriding of the surface section of the electric conduction film of the above 1st into the vacuum tub maintained at the pressure of 10Pa or more,
the electric conduction film top of the above 2nd -- wiring -- public funds -- a group -- the crevice of the electric conduction film of the above 2nd -- the aforementioned wiring -- public funds -- depositing so that a group may be embedded -- the aforementioned wiring -- public funds -- the 4th process which forms the metal membrane which consists of a group
the portion located in the outside of the crevice of the aforementioned insulator layer in the electric conduction film of the above 1st, the 2nd electric conduction film, and a metal membrane -- removing -- the inside of the crevice of the electric conduction film of the above 2nd -- the aforementioned wiring -- public funds -- the embedding wiring formation method characterized by having the 5th process which consists of a group, and which embeds and forms wiring
[Claim 2] The 3rd process of the above is the embedding wiring formation method according to claim 1 characterized by including the process which holds the aforementioned semiconductor substrate and carries out the plasma nitriding of the surface section of the electric conduction film of the above 1st into the aforementioned vacuum tub maintained at the pressure of 50Pa or more.
[Claim 3] the wiring in the 4th process of the above -- public funds -- the embedding wiring formation method according to claim 1 characterized by a group being copper or a copper alloy
[Claim 4] The high-melting point conductivity material in the 2nd process of the above is the embedding wiring formation method according to claim 1 characterized by being titanium, a tantalum, or a tungsten.
[Claim 5] The 3rd process of the above is the embedding wiring formation method according to claim 1 characterized for including the process which performs plasma nitriding where the aforementioned semiconductor substrate is held to ground potential or right potential by things.
[Claim 6] The 2nd process of the above is the embedding wiring formation method according to claim 1 characterized by including the process which deposits the aforementioned high-melting point conductivity material by CVD.
[Claim 7] The 2nd process of the above is the embedding wiring formation method according to claim 6 characterized by including the process in which a part of this high-melting point conductivity material [at least] forms the electric

conduction film of the above 1st in the amorphous state by depositing this high-melting point conductivity material in the temperature field in which crystallization of the aforementioned high-melting point conductivity material is suppressed.
[Claim 8] The 3rd process of the above is the embedding wiring formation method according to claim 1 characterized by including the process which holds the aforementioned semiconductor substrate and carries out the plasma nitriding of the surface section of the electric conduction film of the above 1st into the aforementioned vacuum tub maintained at the pressure of 100Pa or more.
[Claim 9] The electric conduction film of the above 1st is the embedding wiring formation method according to claim 1 characterized by being a titanium-nitride film.
[Claim 10] The 2nd process of the above is the embedding wiring formation method according to claim 1 or 9 characterized by including the process which forms the electric conduction film of the above 1st by depositing the aforementioned high-melting point conductivity material on this titanium-nitride film, after forming a titanium film on the aforementioned insulator layer.
[Procedure revision]
[Filing Date] August 7, Heisei 10.
[Procedure amendment 1]
[Document to be Amended] Specification.
[Item(s) to be Amended] Claim 10.
[Method of Amendment] Change.
[Proposed Amendment]
[Claim 10] The 2nd process of the above is the embedding wiring formation method according to claim 1 or 9 characterized by including the process which forms the electric conduction film of the above 1st by depositing the aforementioned high-melting point conductivity material on this titanium film, after forming a titanium film on the aforementioned insulator layer.

[Translation done.]